

CLAIMS

What is claimed is:

- 5 1. A method of phase-shifting a beam from an electromagnetic beam source in a lithographic process comprising:
- focusing a beam from the electromagnetic beam source onto a mask, the mask adapted to selectively phase-shift at least a portion of the beam according to a predetermined pattern;
- 10 passing the beam from the electromagnetic beam source through the mask producing a phase-shifted beam; and
- directing the phase-shifted beam at a substrate adapted to be selectively etched according to the predetermined pattern.
- 15 2. The method of claim 1 wherein the phase-shifted beam comprises a plurality of beam portions.
3. The method of claim 2 wherein the beam portions include at least a first beam portion and a second beam portion.
- 20 4. The method of claim 3 wherein the first beam portion corresponds to at least one primary feature and the second beam portion corresponds to at least one assist feature.
- 25 5. The method of claim 3 wherein the first beam portion and the second beam portion are at unequal phases.

6. The method of claim 5 wherein the first beam portion is substantially a multiple of 180 degrees out of phase from the second beam portion.
7. The method of claim 1 wherein the phase-shift is a strong phase-shift.
- 5 8. The method of claim 7 wherein the strong phase-shift substantially eliminates zero-order light between the first beam portion and the second beam portion.
9. The method of claim 7 wherein the strong phase-shift is operable to balance opposing electric fields between the first beam portion and the second beam portion.
- 10 10. The method of claim 4 wherein the primary feature is an isolated feature on the mask.
11. The method of claim 4 further comprising forming the assist feature by a subtractive etch process.
- 15 12. The method of claim 4 further comprising forming the primary feature by a subtractive etch process.
- 20 13. The method of claim 1 further comprising forming the mask from a photomask material having a transmittance greater than zero and less than or equal to one.
- 25 14. The method of claim 4 further comprising forming the assist feature by an additive process.

15. The method of claim 4 further comprising forming the primary feature by an additive process.
- 5 16. The method of claim 1 wherein the electromagnetic beam source is an actinic light source.
17. The method of claim 1 further comprising the steps of:
employing an EMF (electromagnetic field) simulator; and
determining a complex transmittance and phase.
- 10 18. The method of claim 4 wherein the at least one assist feature comprises multiple pairs of assist features.
19. The method of claim 4 wherein the at least one primary feature comprises two
15 dimensional primary features.
20. A phase-shift mask adapted to selectively phase-shift a beam from an electromagnetic beam source comprising:
a phase-shift mask comprising a photomask material adapted to transmit
20 the beam as a phase-shifted beam, the mask having a plurality of portions according to a predetermined pattern,
the portions further comprising :
at least one first shift portion adapted to transmit the beam according to
the predetermined pattern, the first shift pattern operable to shift the beam
25 according to a first phase-shift to produce a first beam portion;
at least one second shift portion adapted to transmit the beam according
to the predetermined pattern, the second shift portion operable to shift the beam
according to a second phase-shift to produce a second beam portion.

21. The phase-shift mask of claim 20 wherein the photomask material is quartz.
22. The phase-shift mask of claim 20 wherein the phase-shifted beam comprises a plurality of beam portions.
23. The phase-shift mask of claim 20 wherein the first beam portion corresponds to at least one primary feature and the second beam portion corresponds to at least one assist feature.
24. The phase-shift mask of claim 23 wherein the first beam portion and the second beam portion are at unequal phases.
25. The phase-shift mask of claim 24 wherein the first beam portion is substantially a multiple of 180 degrees out of phase from the second beam portion.
26. The phase-shift mask of claim 20 wherein the phase-shift is a strong phase-shift.
27. The phase-shift mask of claim 26 wherein the strong phase-shift substantially eliminates zero-order light between the first beam portion and the second beam portion.
28. The phase-shift mask of claim 27 wherein the strong phase-shift is operable to balance opposing electric fields between the first beam portion and the second beam portion.
29. The phase-shift mask of claim 23 wherein the primary feature is an isolated feature on the mask.

30. The phase-shift mask of claim 23 wherein the assist feature is formed by a subtractive etch process.
- 5 31. The phase-shift mask of claim 23 wherein the primary feature is formed by a subtractive etch process.
32. The phase-shift mask of claim 20 further comprising forming the mask from a photomask material having a transmittance greater than zero and less than or equal to one.
- 10 33. The phase-shift mask of claim 23 wherein the assist feature is formed by an additive process.
- 15 34. The phase-shift mask of claim 23 wherein the primary feature is formed by an additive process.
35. The phase-shift mask of claim 20 wherein the mask is operable to transmit light from an actinic light source.
- 20 36. The phase-shift mask of claim 23 wherein the at least one assist feature comprises multiple pairs of assist features
37. The phase-shift mask of claim 23 wherein the at least one primary feature
- 25 comprises two dimensional primary features.